Climate Impacts of Solar Cycle and Quasi-Biennial Oscillation: From the Polar Area to Mid-latitude

Presenter: Lin Tan [1]

Co-author: Andrew Bai[2,3], Annie Bai[3], King-Fai Li[1], Ka-Kit Tung[4], ShuHui Wang[2]

[1] University of California, Riverside, CA
[2] University of California, Berkeley, CA
[3] St. Paul Academy and Summit School, St. Paul, MN
[4] University of Washington, WA

Background

- Extratropical stratospheric interannual variability is compounded by the nonlinear effects of the **Solar Cycle (SC**) and the **Quasi-Biennial Oscillation (QBO).**
- Observed modulation by the QBO/SC to the winter pole:

1. Easterly QBO (eQBO) phase
    - More vortex breaking and stratospheric sudden warmings (SSWs) through the Holton-Tan mechanism [*Holton & Tan*, 1980; *McIntyre*, 1982].
2. 11-year solar maximum (SCmax)
    - The polar stratospheric changes are similar to those of eQBO. The Holton-Tan mechanism is likely also responsible for the Solar Cycle [*Camp & Tung*, 2007].

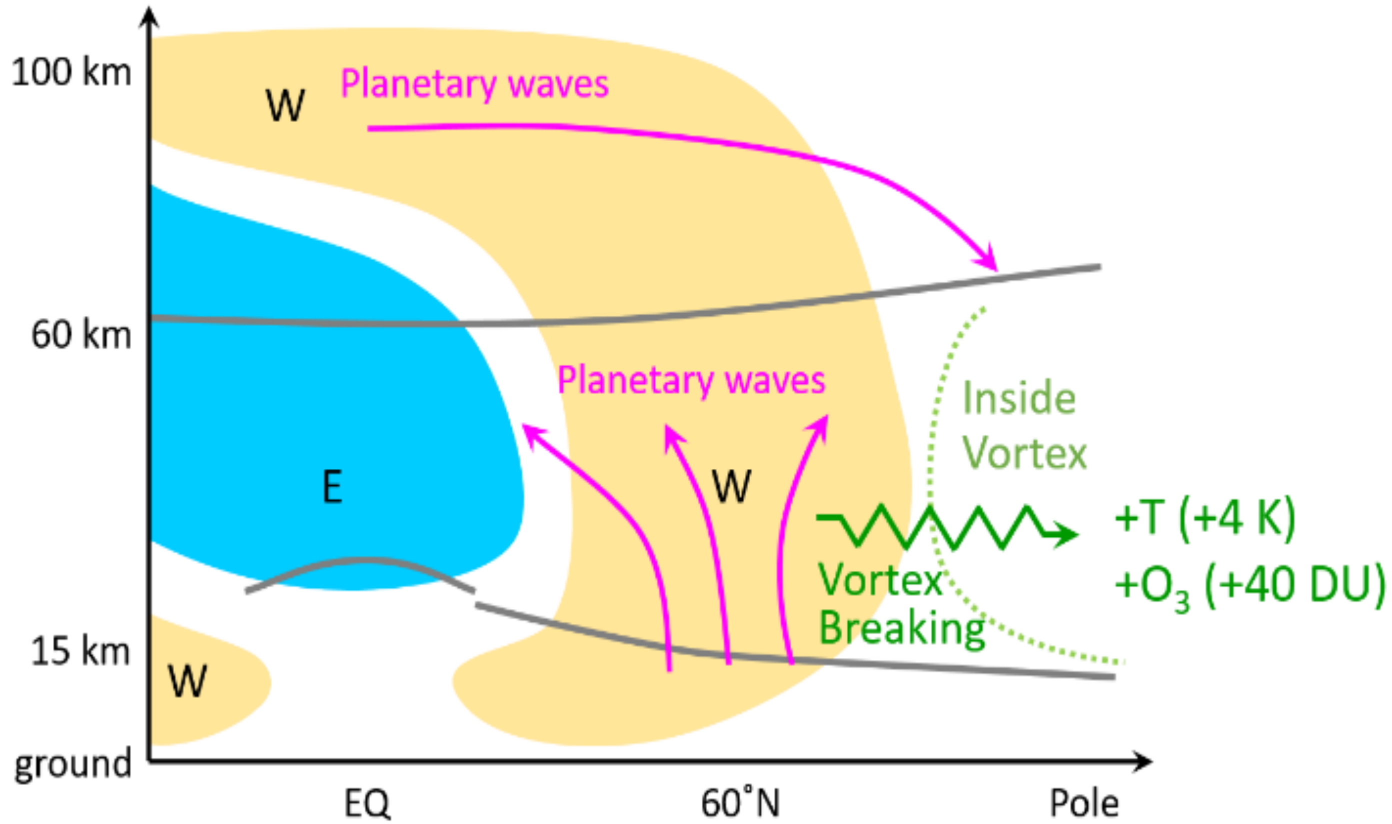

Figure 1. Graphical summary of Holton & Tan's [1980] results.

- Either **eQBO** or **SCmax**, or both, leads to 4 K and 40 DU increase in polar temperature and ozone inside the vortex [*Camp & Tung*, 2007; *Li & Tung*, 2014].

- As a follow up study, we define the **wQBO/SCmin as the quiescent state** and compare the **temperature anomalies** across different combinations of QBO and SC phases.

Objective

To study the **indirect impacts** of the **coupled QBO/SC forcing** on the **mid-latitude temperature.**

Idea highlight:

- We use 60 years (1954 - 2014) of NCEP-1 reanalysis data to examine the effects of QBO/SC on mid-latitudes by looking at the temperature anomaly) of the 3 excited states from the quiescent state(wQBO/SCmin).

Some Detailed Methodology

- wQBO index was defined when the zonal wind above Singapore is greater or equal to 4 m s^{-1} while eQBO was identify as –4 m s^{-1}.

- The annually averaged $F_{10.7}$ solar flux is used to define the solar maximum ($\geq$ 140 s.f.u.) and minimum ($\leq$ 125 s.f.u.) conditions.

	Solar Cycle Minimum	Solar Cycle Maximum
Westerly QBO	**Quiescent state** WQBO, SC min	WQBO, SC max
Easterly QBO	EQBO, SC min	EQBO, SC max

Result

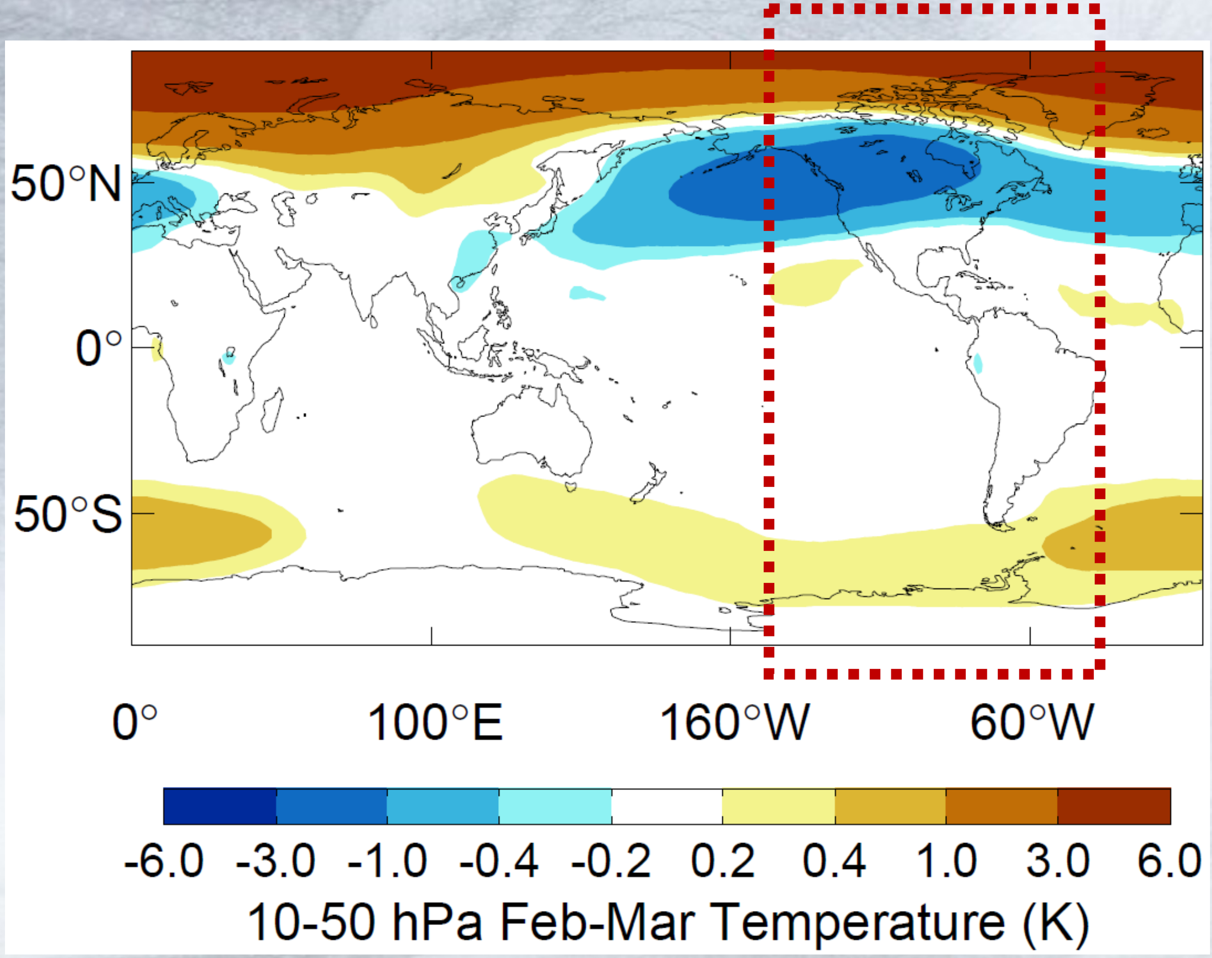

Figure 2. Stratospheric temperature anomaly relative to the quiescent state.

At the stratosphere…

- A planetary-scale **cold anomaly in the stratosphere (10-50hPa) over North America is observed.**
- Indicating an exchange of airmass between the polar region and mid-latitudes during the major warming event.

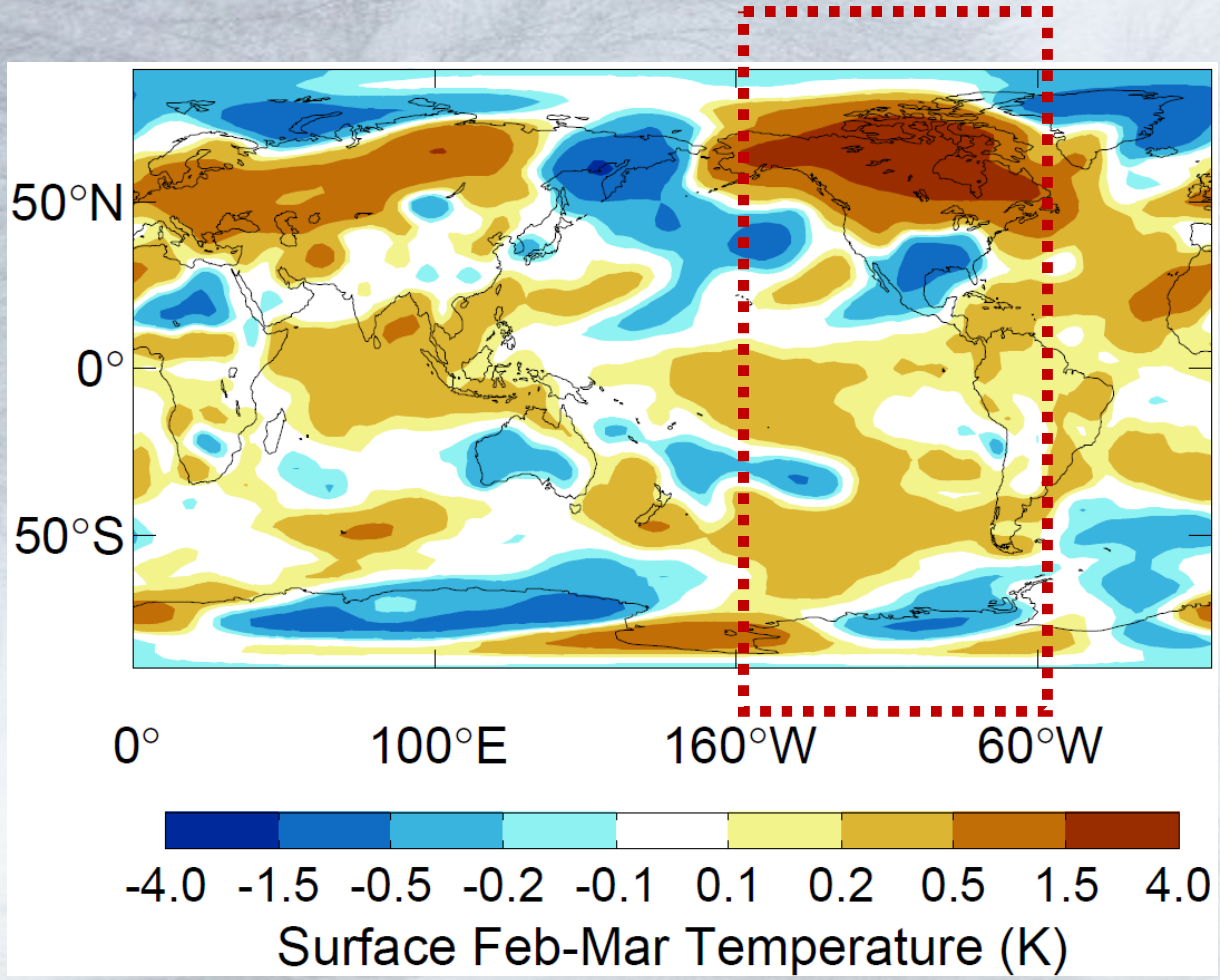

Figure 3. Surface temperature anomaly relative to the quiescent state.

What about the surface?

The **stratospheric cold anomaly extends downward** to the surface in the southern US, leading to a temperature decrease of 0.5–1 K relative to the quiescent state.

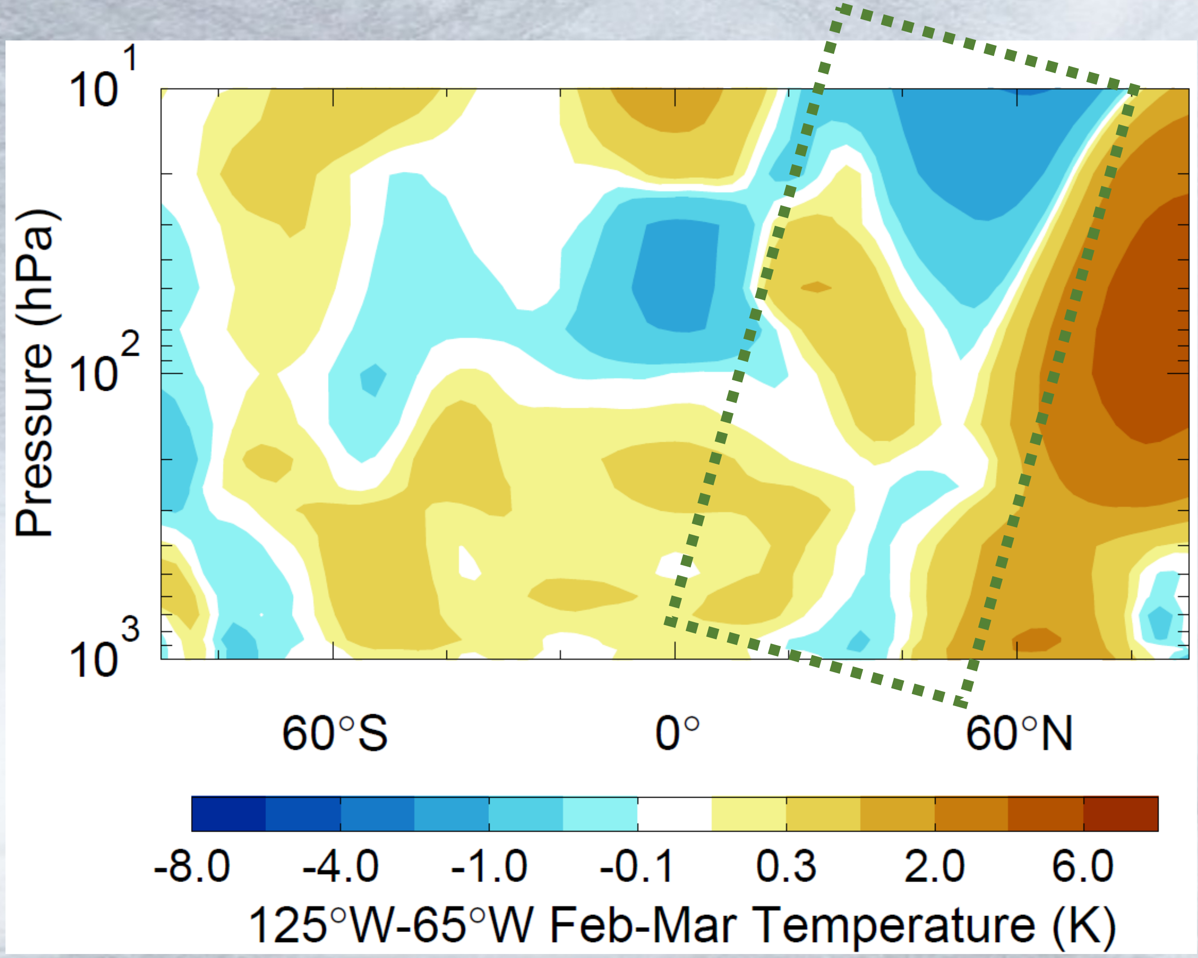

Figure 4. Vertical cross-section of the temperature anomaly

Stratosphere - Surface

- To show more clearly the downward propagation, a cross-section of the temperature difference over North America (135°W–65°W) is shown on the left.
- The green box highlights the downward propagation over the southern US.

Conclusion

- The Solar Cycle and the QBO may indirectly modulate regional mid-latitude weather through their impacts on polar dynamics.

- Possible mechanisms that relate the breaking of polar vortex at stratosphere and the transport of the cold air into the troposphere at the mid-latitude require further examinations.